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Research methods adopted for evaluation of the condition of the building materials used in construction of the masonry structures on the site of the Auschwitz-Birkenau State Museum in Oświęcim

Teresa Stryszewska[a,*], Stanisław Kańka[a], Agnieszka Żydzik-Białek[b]

[a] *Cracow University of Technology, Warszawska 24, 31-155 Kraków, Poland*
[b] *Auschwitz-Birkenau State Museum in Oświęcim, Więźniów Oświęcimia 20,32-603 Oświecim, Poland*

Abstract

The article shows the extent of work carried out within the framework of the project Research on the development of methods of maintenance, security and strengthening the structure of objects, elements of their finish and substrate, taking into account the statics and physics of the buildings within the Auschwitz-Birkenau State Museum in Oswiecim, as part of the multi-annual program of comprehensive, systematic preservation activities aimed at preserving the Auschwitz-Birkenau Memorial. The project is funded by the Auschwitz-Birkenau Foundation.
The aim of the project was to create a base of information on the actual condition of the existing facilities and, on that basis, to develop preservation methods and ways to prevent their further destruction while maintaining their current character.
The article presents the results of the research into the condition of the structural materials done – as an example – on one of the elements of the camp technical infrastructure – the wastewater treatment station. It also describes how the research itself was done. The scope included finding out the compressive strength of the masonry, bricks and mortar as well as determining the content of sulphate, chloride and nitrate salts both in the bricks and mortar. The article discusses the results of macroscopic and microscopic observations done on bricks and mortar using scanning microscopy.

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Keywords: masonry degradation; technical condition

* Corresponding author. Tel.: +48 12 628-23-45; fax: +48 12 628-23-67.
*E-mail address:*tstryszewska@pk.edu.pl

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1. Introduction

The works aimed at preserving for future generations the Auschwitz-Birkenau extermination camp memorial in Oświęcim, Poland – a place which witnessed the tragic events of the II World War – have been carried out on the site of the camp since 2009. An extensive research programme has been initiated in order to complete this task, which included the following:

- geotechnical examination of the foundation,
- developing an inventory of the deformations of the structures and the scope of corrosion damage,
- macroscopic description (full photographic documentation),
- examination of the physical properties of the materials used to build the structures,
- tests of strength,
- determining the degree of salinity of the mineral construction materials.

The results obtained in the research constitute a database of information necessary for developing adequate conservation methods, i.e. ways in which the built structures could be protected from further degradation. One of the components of the programme was to obtain data describing the actual condition of the facilities, the degree of their degradation and the factors affecting the preservation of the built structures used as museum facilities accessible to visitors.

Apart from the prisoners' barracks, the site of the Auschwitz II-Birkenau extermination camp in Brzezinka also includes camp infrastructure facilities, such as storehouses, kitchens, washrooms, latrines, sewage treatment stations, etc. One of such facilities – the tricking filter, a component of the camp sewage treatment station – has been used by the authors as an example on which they have presented the adopted method of examining the materials in a masonry structure as well as the obtained results and their interpretation.

The facility in question is a tank, 20 m in diameter, built of solid ceramic brick. The walls are approximately 5 m high and 0.5 m thick. In its central part there is a channel for sewage distribution. Originally, the walls of the tank were covered with cement plaster on the inside. At the bottom of the tank there are distribution channels, cast in concrete, covered with a grid of prefabricated concrete slabs. The outlet channel runs on the outside of the tank along its perimeter. Because of the outward inclination of the trickling filter's walls, it was necessary to place two steel bracing bands around the structure to hold it together, which was done in the post-war period. The inclination of the walls was the reason of cracking and the appearance of prominent fissures. Fig. 1 shows the present condition of the two twin trickling filters, respectively. The facilities have never been covered with any roofing, so they were and still continue to be exposed to all kinds of weather conditions. It must be added that the construction of the filters had not been completed and they were never used for the purpose they had been built for.

Fig. 1. The trickling filters of the camp sewage treatment station – current condition.

The aim of the research presented in the article, carried out within the research project, was to examine the condition of mineral materials in the trickling filter in question. The scope of the research encompassed the following:

- macroscopic description, complete with photographic documentation, of the characteristic types of damage observed in the walls,
- observations of the microstructure of the ceramic material which has undergone various forms of destruction,
- determination of physical and strength properties of the materials sampled from the walls,
- determination of the degree of salinity of the ceramic brick and mortar in the walls.

2. The research methodology

The examination of the mineral materials collected from the facilities – presented in this article – has been done in compliance with the mandatory research procedures of the Accredited Testing Laboratory for Building Materials and Structures at Cracow University of Technology, which have been developed for the needs of the research project. The procedures are based on the literature on the subject [1–4], as well as the relevant standards. The research on the materials from which the tank walls were made was done on the samples collected in the form of cores taken from the wall (brick together with mortar, 100 mm in diameter) and ceramic brick (25 mm and 50 mm in diameter).

The choice of places where the samples were to be bored had been consulted and approved by the conservation department of the museum, but in a way allowing analysis of the selected material properties in relation to the height of the walls. The sampled materials were examined as to their moisture content, density and compressive strength of the wall, brick and mortar. Chemical analysis has also been done in order to determine the content of salts affecting the durability of the examined materials. The microstructure of the bricks and mortar has been studied with the use of a scanning microscope.

2.1. Macro and microstructure examination

The description of the macroscopic destruction of the mineral materials was based on the examinations carried out in situ during a field trip and on photographic documentation. The microstructure has been examined with the use of a scanning microscope equipped with a detector enabling creation of a morphology and topography image (VSPE and SE) as well as the phase contrast image (BSD). The examination was carried out on unsprayed, previously fractured samples.

2.2. Examination of the moisture content

The actual moisture content in the ceramic brick and the wall has been determined for all the samples collected in the form of cores from the masonry walls. The moisture content has been determined with the use of gravimetry [5,6]. The actual moisture contents in the sampled materials were calculated on the basis of mass measurements.

2.3. Examination of the bulk density

Bulk density was determined on regular-shape samples, in the case of the ceramic brick – in the dry condition, whereas in the case of the internal plaster – in the condition of natural moisture content. The measurements of mass and volume were the basis for determination of the examined materials density.

2.4. Examination of the compressive strength

The compressive strength of the brick was examined on cylinder samples prepared from cores 50 mm in diameter. The samples for testing this property were cylinders of the height equal to their diameter. Prior to testing, opposite faces of the cylinders had been polished off in order to obtain smooth and parallel surfaces. Samples thus prepared were subjected to compression strength tests in a materials testing machine so that the value of crushing force could be determined.

The mortars' compressive strength was tested on fragments collected together with the ceramic brick. A mortar sample of the thickness equal to the actual joint in the wall was placed between two pins 20 mm in diameter and subjected to loading through the medium of two thin layers of gypsum grout. The plaster samples taken from the internal face of the walls were tested in the same way [7].

The compressive strength of the walls was tested on cylinder samples of the length equal to the width of the brick, i.e. approximately 120 mm, and the diameter of 100 mm, prepared from cores. The sample was placed in the materials testing machine in a way reflecting its position in the wall (nested in specially shaped pads) and subjected to loads to the point of destruction [5, 6]. Fig. 2 illustrates the methods in which the compressive strength of the materials collected from the structure was tested.

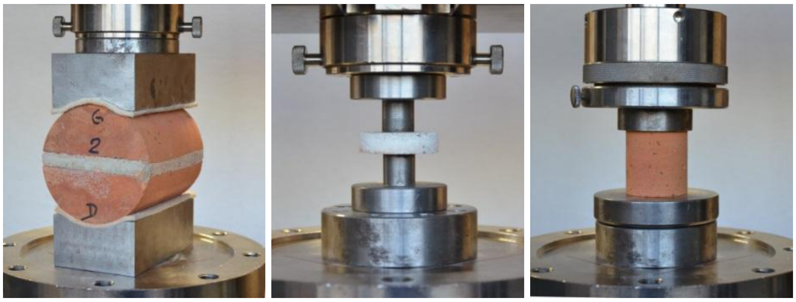

Fig. 2. Testing the compressive strength of the wall, mortar and brick (from left to right).

2.5. Examination of the content of salts

The scope of the chemical analysis also included determination of the pH value and of the content of sulphates, chlorides and nitrates in the ceramic bricks, mortar and plaster. Chemical properties were tested on samples of the materials obtained from cores, which were subsequently ground and mixed with water in the ratio of 1:5 (powdered material / distilled water). The chemical analysis was carried out with the use of certified tests applying the spectrophotometric method. The contents of sulphates, chlorides and nitrates were expressed as percentage ratio in relation to the mass of the whole sample. The pH value measurements of the water extraction were done with a digital pH meter equipped with a combined electrode.

2.6. Examination of the mortars composition

Determination of the mortars composition consisted in finding out the contents of the binder and the aggregate in proportion by mass. For this purpose a sample of the mortar – dried to constant mass, weighed and ground – was dissolved in hydrochloric acid of 15% concentration. Next, in the process of filtration, the filtrate was separated from the aggregate. The ratio of the binder to the aggregate (b/a) was determined on the basis of the mortar sample mass and the mass of the dried aggregate left after the binder had been dissolved.

2.7. Examination of vapour permeability

In order to explain why the plaster and the wall on the inside of the tanks have degraded to such a considerable degree, apart from the generally accepted scope of examination to which the facilities situated on the site of the ABSM in Oświęcim were subjected, the plaster and ceramic bricks were additionally tested for absorbability and water vapour permeability. Loosened bits of bricks and plaster were collected for the tests, of which samples were made – 15 mm thick and 50 mm in diameter. The method of sample preparation and marking has been presented in Fig. 3. Following [8], it has been assumed that the test result is the density of water vapour flux penetrating through a given material, calculated on the basis of water mass loss in the adopted measurement system.

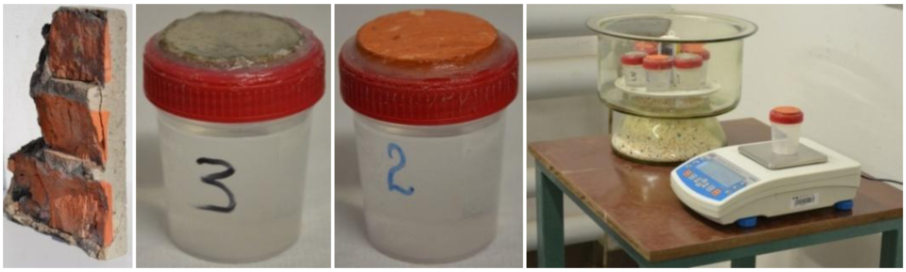

Fig. 3. Samples for testing vapour permeability and the method of measurement.

3. Results of the examination and their analysis

3.1. Macro- and microscopic observations

The facility in question is a masonry structure made of solid brick with cement-lime mortar. The walls on the inside were covered with cement plaster (smooth floated finish), of which only a few fragments have been preserved until today. At present the condition of the bricks and mortar inside the facility is characterised by a considerable degree of destruction. On the other hand, the external face of the wall is distinctly better preserved, although certain white and grey efflorescence is distinctly visible, which indicates the presence of mineral salts in the material. The crown of the tank is significantly degraded, which enables deep penetration of rainwater into the walls. Fig. 4 presents the view of the trickling filter wall from the outside and the inside of the facility, respectively. Figures 5 and 6 present the most typical examples of the wall surface damage, i.e. peeling off, crumbling, stratification, efflorescence and biological destruction. Observations of microstructure were carried out at selected places with the use of a scanning microscope and the EDS analysis was performed. The obtained results are presented in Figures 7 and 8.

Fig. 4. The trickling filter – view from the outside, view from the inside (from left to right).

Fig. 5. Macroscopic image of the wall damage.

Fig. 6. Macroscopic image of efflorescence formations and microorganisms present at the surface of the wall (from left to right).

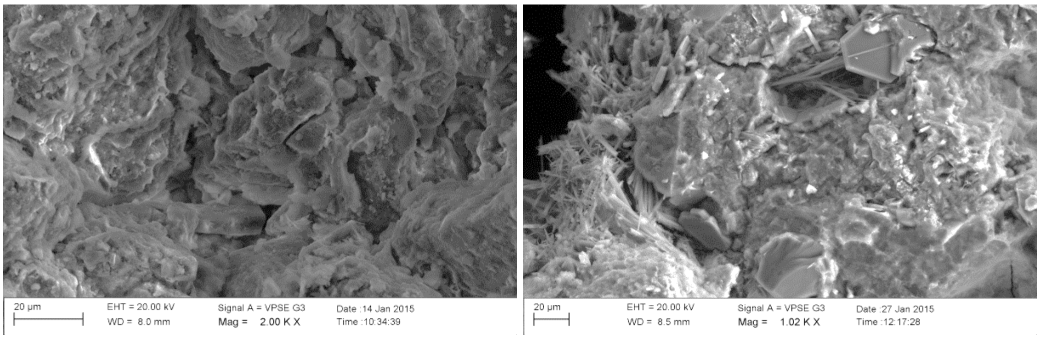

Fig. 7. An example image of the microstructure of the degraded bricks and mortar (from left to right).

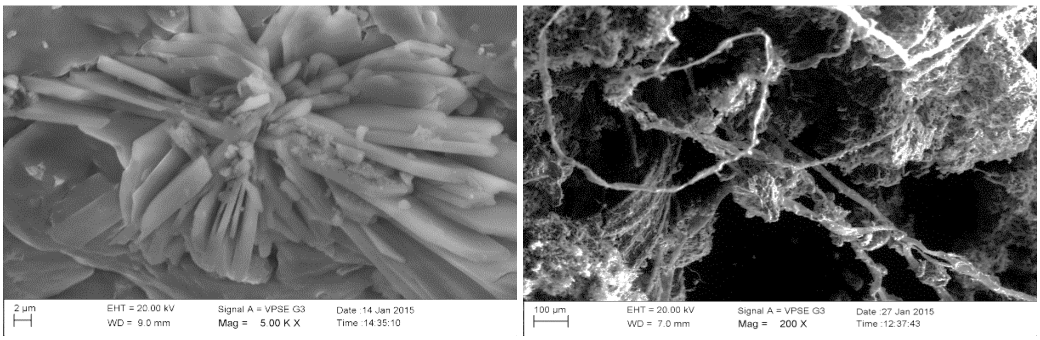

Fig. 8. An example image of the microstructure showing efflorescence and microorganisms on the surface of the materials (from left to right).

Examination of the microstructure of the destroyed ceramic bricks indicated loosening of texture with clear peel-off surfaces. The presence of ettringite and calcium carbonate was observed as well as numerous cracks. Chemical analysis of efflorescence on the wall surface carried out with the use of EDS confirmed the presence of gypsum and calcium potassium sulphate as its primary components. Another destructive factor was the presence of microorganisms, such as moss, lichen and fungi.

On the basis of macroscopic observations it has been found that the degree of damage is greater in the case of the ceramic brick than in the case of the mortar. The process of mortar degradation was related inter alia to binder carbonation, leaching of soluble ingredients, including calcium hydroxide, and to the emergence of both readily soluble substances, which were then easily leached, and insoluble products increasing the volume. The visible effect is loosening of the mortar texture and crumbling.

3.2. Results of physical and mechanical properties examination

The results of physical and mechanical properties examination are presented in Table 1. They are shown as ranges of values for individual properties obtained in the tests done on at least 4 samples.

Table 1. Physical and mechanical properties.

Tested material	Moisture content [%]	Density [kg/m^3]	Compressive strength [MPa]
Ceramic masonry	1.64÷3.81	not determined	10.7÷23.8
Ceramic brick	0.55÷2.44	1650÷1810	12.2÷24.1
Mortar	not determined	1633÷1761	16.2÷26.2
Cement plaster	1.12÷1.96	1826÷1946	63.5÷75.5

The moisture content of the tested materials varied and was clearly dependant on the season of the year in which the samples were collected. The results of moisture content tests presented in Table 1 are for the samples collected in the summer. It has been demonstrated that at that time the walls were characterised by acceptable moisture content [6], whereas the moisture content of materials samples collected in the winter was discernibly higher – from a few to even more than ten per cent. It may be concluded that the continuous changes in the amount of moisture in the walls have had certain influence on the intensification of the wall degradation processes resulting from salts crystallisation in the subsurface zones and on the surface of the walls [9].

The evaluation of the wall compressive strength took into account the strength of the ceramic brick, mortar and the masonry as a whole. The obtained values of masonry strength varied discernibly and ranged from 10.7 to 23.8 MPa. However, strength was tested on the samples collected from places where the masonry condition allowed boring a hole, so the assessment of the load-bearing capacity of the walls must take into account the fact that the facility in question includes wall sections where the strength is lower than the above-mentioned minimum value. The examination of compressive strength of the plaster and mortar was done with the use of a non-standard method, which was employed following the literature on the subject [7]. The tests indicated that the plaster was characterised by high strength, the highest of all the tested materials. Yet, it has been almost completely destroyed, only a few fragments have remained in place on the internal face of the filter wall.

3.3. Results of the chemical tests

The results of tests for the contents of sulphate, chloride and nitrate salts as well as the pH values are presented in Table 2. They are shown as ranges of values for individual properties obtained in tests done on 4 samples.

Table 2. The pH value and the contents of mineral salts in the materials of the wall.

Tested material	Location	Ratio b/a	pH	Content of ions [%] sample mass		
				SO_4^{2-}	Cl^-	NO_3^-
	top		7.2÷8.7	0.08÷0.93		
Ceramic brick	centre	not determined	7.2÷8.7	0.01÷0.99	≤0.01	≤0.01
	bottom		7.4÷7.6	0.07÷0.28		
Mortar	centre	1/1.3÷1/1.7	9.1÷11.7	0.01÷1.08	0.01÷0.05	0.01÷0.12
Cement plaster	centre	1/2.6÷1/4.3	11.9÷12.6	0.01÷1.72	0.01÷0.02	≤0.01

Chemical tests of the brick, mortar and plaster indicated low concentrations of nitrate and chloride ions and medium concentrations of sulphate ions. Thus, taking into account the results of the chemical analysis of all the ions, it has been found that the walls of exhibit a medium degree of salinity [10]. The pH value of the tested bricks was close to neutral and did not indicate the presence of any corrosion products of acidic character. The pH value of the mortars, on the other hand, was slightly low, the pH value below 9 may indicate binder decay and the presence of calcium carbonate or other salts of poor solubility, which are the products of this material corrosion. In the case of the plaster, the content of chloride and nitrate salts was very low, with the exception of sulphate salts, which varied within the range between 0 to 1.7 % of the sample mass. The generally low degree of salinity and high pH value of the cement plaster indicate the physical nature of the mechanism responsible for this material destruction.

3.4. Results of the vapour permeability and absorbability tests

The obtained results of vapour permeability and absorbability tests are presented in Table 3. They are shown as ranges of values for individual properties obtained in tests done on 4 samples.

Table 3. Vapour permeability and absorbability.

Tested material	Water vapour flux density [kg/m^2h]	Absorbability of water [%]
Ceramic brick	$5.94 \div 12.89 \times 10^{-3}$	15.8÷19.5
Cement plaster	$1.33 \div 1.57 \times 10^{-4}$	9.8÷11.4

The ceramic brick absorbability was clearly higher than the plaster absorbability. The tests indicated that the brick vapour permeability was approximately 100 times higher than in the case of the plaster, and the results for the bricks were more varied. The initially waterproof plaster layer of high strength was to protect the walls of the tank from being affected by the sewage collected therein. Since the structures had never been completed and the upper layers of the walls had not been properly insulated, the tanks were exposed to the environmental impact, including rain - and snowfall, groundwater capillary rise, drying and temperatures below zero. Additionally, over time the walls of the facilities started to gradually lean outwards, which resulted in the emergence of wide cracks and fissures. This in turn made the walls more readily accessible to the operation of water, especially rainwater, which penetrated deep inside the walls. The water-saturated wall would dry up in warmer seasons and the water would evaporate. Due to the presence of a relatively waterproof material on the inside face of the wall, the water was not drained off freely. From the point of view of the physics of the structure, the plaster was a barrier separating areas of distinctly different water content, i.e. the inside of the wall, approximately 0.5 m thick, saturated with water, and the external environment. In such case, the water vapour concentration gradient caused water transmission in the direction of the area of lower moisture content [11]. The rise in pressure, related to the presence of water vapour, resulted in bits of plaster peeling off the wall together with fragments of brick and exposing the ceramic bricks and mortar. Additionally, the destruction process was intensified by freezing temperatures. Seasonal freezing of water within the texture of the materials brought on frost destruction.

4. Conclusions

The primary aim of the presented analysis was to obtain information on the present condition of materials in masonry structures. The obtained data will be used in developing a plan of preservation and protection of the facilities granted full conservation and maintenance guarantee by the state authorities. The works' priority was to preserve and strengthen all the original parts of the structures demonstrating the prisoners' living conditions in the extermination camp.

The authors have used one facility – a component of the camp wastewater treatment station – as an example on which they have presented the adopted method of examining the walls in selected masonry structures located on the site of the former Auschwitz II-Birkenau extermination camp in Brzezinka. Additionally, they have been able to explain why the plaster on the walls inside the trickling filter has degraded almost completely. They have demonstrated that the primary factor contributing to the degradation was the difference between vapour permeability of the plaster and of the ceramic bricks. The microstructural tests they have carried out allowed them to characterise the ongoing destructive processes. An extensive photographic documentation was collected in the course of the works, illustrating the damage of the materials in the existing facilities, which also served as the basis for the evaluation of their technical condition. The evaluation has been supported by the results of a number of laboratory tests, which yielded quantitative values of many physical and mechanical properties of the materials in the walls of the facilities in question, over 70 years after they had been built.

Acknowledgments

The research has been done within the framework of the research project Research on the development of methods of maintenance, security and strengthening the structure of objects, elements of their finish and substrate, taking into account the statics and physics of the buildings within the Auschwitz-Birkenau State Museum in Oświęcim financed by the Auschwitz-Birkenau Foundation.

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